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EXPERIMENTAL STUDY OF PRECAST ROAD PANEL DESIGN USING SOY BEAN HUSK ASH AND KOTA STONE DUST AS A CEMENT REPLACEMENT MATERIAL UNDER CYCLIC, STABILITY AND FATIGUE LOADING

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Abstract
Many agricultural and industrial wastes like rice husk ash, fly ash etc., have proven themselves as an efficient replacement of cement in concrete mixtures. The need for replacing cement is rapidly increasing for its economic and environmental advantages. Precast roads are the solution for immediate construction, repair and maintenance of roads for the expansion of the traffic. In this study, we study the physical and chemical properties of Soybean Husk ash and Kota Stone Dust as a replacement material for cement in a concrete mix and try to determine the optimum content in the mix and determine the strength parameters of the same. We make a precast road panel with the optimum dose of Soybean Husk Ash and Kota Stone Dust and study its behaviour under various loadings. This study will summarize the pozzolanic behaviour of Soy bean husk ash and Kota Stone Dust and effectiveness of precast roads under monotonic, cyclic and Fatigue loading.
Keywords: Soybean Husk Ash (SHA), Precast Road Panels (PRP), Kota Stone Dust (KSD), Design Mix (DM), Nominal Mix (NM), Cyclic Loading.

I. Introduction

Human activities generate a large amount of solid waste, and the disposal of these solid waste materials poses an environmental risk to nearby living beings. Putting solid waste to good use is the most effective way to reduce the problems associated with it. The use of solid waste materials as construction materials has enormous potential in the construction industry. Depending on their properties, solid waste materials can be used as supplementary cementitious materials or as fine or coarse aggregate replacements in concrete or mortars. Because of their economic and environmental benefits, some solid waste materials, such as fly ash, silica fume, grounded blast furnace slag, and so on, have been used in the production of cement or concrete.

The increasing number of vehicles overloads many roads far beyond their design capacities, causing pavement to deteriorate at a faster rate. Highways are frequently closed to address this degradation by constructing new pavements, overlays, or replacement and removal implementations. We try to reduce the impact of such construction traffic delays and speed up pavement construction by using precast roads. Precast road panels will combine the benefits of both types of pavements, allowing for quick construction and low maintenance. Because precast concrete pavements are manufactured in a controlled environment, there is no room for early age cracks or other environmental distresses.

II. Material Selection:

2.1 Soybean Husk Ash (SHA): Production of soybean in India is dominated by Maharashtra and Madhya Pradesh which contribute 89 per cent of the total production. Due to abundance of soybean farming in nearby areas, there is a huge amount of husk that is leftover after the crop season. In our study we will use the same husk, burn it and use it in our concrete mix. We will try to learn about the pozzolanic properties of soybean husk ash and its strength parameters in concrete mixes. Already, Rice husk ash, wheat husk ash has shown promising results as a replacement material in concrete and various researches are going around with other waste materials.

2.2 Kota Stone Dust (KSD): It is a fine-grained, dimensional stone with a naturally split, non-slip surface and an amorphous texture that is sometimes referred to as "splitable" or "flaky" limestone. These characteristics qualify it for commercial use, and it has been used for display purposes in public and private buildings for tiling and flooring. With the passage of time, the popularity of this stone has grown around the world, and it is now preferred over other well-known and expansive dimensional stones such as granite and marble. The quarrying and processing of Kota stone generate a massive amount of waste. Nearly 1.2 million tonnes of Kota stone waste in slurry and dust form are being disposed of at various locations. Out of total waste production, blasting generates 50–60% of waste, and mechanised cutting, mining, and polishing methods generate 30–40% of total waste.

Figure 1: Soybean Husk Ash

Figure 2: Kota Stone Dust

III. Experimental Details

3.1 Chemical Composition of the Materials: The raw materials used to produce cement are primarily lime, silica, alumina, and iron oxide. At high temperatures, these oxides interact with one another in the kiln to form more complex compounds. The relative ratios of these oxide compositions impact the multiple characteristics of cement, as well as the rate of cooling and fineness of grinding. The Chemical Compositions of OPC, SHA from K. J. Taku et. al. [2], and KSD from Harshwardhan SC et. al. [13] are given in the following table:

Oxide	OPC 53 Composition (%)	SHA Composition (%)	KSD Composition (%)
CaO	61.85	15.78	37.85
SiO_2	20.07	32.62	23.5
Al2O_3	5.32	4.58	3.1
Fe_2O_3	4.62	1.46	1.94
MgO	0.83	8.33	-
K_2O	-	20.96	-
Na_2O	-	0.85	-
SO_3	2.5	0.47	-

Table 1: Chemical Compositions of Materials

3.2 Material Properties: The Specific gravity of OPC 53 grade cement was 3.17, Consistency 30%, Initial Setting Time 95, Final Setting Time 480 and based on the mortar testing of the cement the average 7-days compressive strength was 38.49 and 28-days compressive strength was 54.84. The Specific gravity of fine aggregates was found to be 2.73, fineness modulus 3.51 and water absorption was 1.4. For coarse aggregate specific gravity was 2.76 and 2.8, fineness modulus 3.066 and 3.038 for 20mm and 10mm respectively. Specific gravity of 2.08, fineness modulus 4.34 and water absorption of 20% for SHA was tested.

3.3 Details of Mix Design: Concrete Mix Designs of M40 grade and M65 grade of concrete were prepared as per IRC: 44-2017. Table below shows the material requirements of M40 and M65 grades of concrete with and without replacements of SHA and KSD.

Grade of Concrete	Replacement (%)	Cement	Coarse Aggregates (kg/m3)	Fine Aggregates (kg/m3)	Water (kg/m3)	SHA (kg/m3)	KSD (kg/m3)
M40	0	413.33	1286.54	668.26	148.87	0	0

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	25	310.04	1286.54	668.26	148.87	41.3	61.99
M65	0	434.48	1487.44	517.03	126	0	0
	25	325.968	1487.44	517.03	126	43.34	65.172

Table.2: Mix Proportions for Nominal Mix and Design Mix

IV. Methodology

4.1 Preparation of Specimens: The cubes are of standard size with 150x150x150mm. Cylinders used of size diameter 150 mm and height of 300 mm. For the casting of beams, moulds have been prepared first of size 500mm x 100mm x 100mm. For casting of panels, wooden planks were used of the size 375mm x 375mm x 200mm. All these moulds are tightened first and applied oil inside of them.

Determination of Optimum Dosage: Mortar cubes of 7cm x 7cm x 7cm were casted and tested for 7-days and 28-days strength. Following results were obtained at different percentages of compressive strength:

% Replacement	Compressive Strength	
	7 Days	28 Days
0	34	47.21
5	26.2	31.5
7.5	27.54	34.21
10	28.59	35.98
15	21.7	27

Table.3: Optimum Dosage of SHA

% Replacement	Compressive Strength	
	7 days	28 days
0	34	47.21
5	32.45	44.31
10	34.87	48.68
15	35.21	50.21
20	31.03	42.15

Table.4: Optimum Dosage of KSD

The best results in mortar tests were found at 10% for SHA and 15% for KSD. With these optimum dosages we prepared the design mixes for M40 and M65 grades of concrete and specimens were made for our testing purposes.

V. Results and Discussions

5.1 Compressive strength: Compressive strength of M40 grade and M65 grade concrete without replacement and with replacement are tabulated below. Cubes of dimensions 150mm x 150mm x 150mm were casted and curing for 7 and 28 days was provided for the specimens.

Grade of Concrete	Without Replacement		With Replacement	
	7 Days	28 days	7 Days	28 Days
M40	40.23	43.44	38.54	41.26
	36.83	46.54	35.88	43.65
	38.54	47.08	36.21	42.55
M65	49.82	65.72	43.82	59.56
	63.77	69.49	39.18	67.29
	61.54	71.03	43.26	64.82

Table 5: Compressive Strength of Cube Specimens

5.2 Flexure Strength: Beam specimens of size 500mm x 100mm x 100mm were casted with and without replacement and tested were performed on UTM (Universal testing Machine) and following results were obtained.

Grade of Concrete	Without Replacement		With Replacement	
	7 Days	14 days	7 Days	14 Days
M40	3.13	4.31	4.46	4.86
	3.43	4.7	4.02	6.55
M65	2.74	5.49	3.13	6.67
	2.9	7.06	2.54	5.75

Table 6: Flexure Strength of Beam Specimens

5.3 Split Tensile Strength: Cylinder specimens of size 150mm diameter and 300mm height were casted with and without replacement and tests were performed on UTM (Universal testing Machine) and following results were obtained.

Grade of Concrete	Without Replacement		With Replacement	
	7 Days	28 days	7 Days	28 Days
M40	2.41	3.32	2.26	3.14
	2.14	2.89	1.97	3.61
M65	3.98	4.21	3.31	3.92
	3.75	4.46	2.85	4.08

Table 7: Tensile Strength of Cylinder Specimens

5.4 Behavior of M40 & M65 grade Cylinders under various Loadings: The results of Cylinders specimen of M40 and M65 grade of concrete under Monotonic loading, Cyclic loading and Stability loading. First, we performed monotonic load on the cylinder to get the value of maximum load from which we decided the load cycles for cyclic and Stability loading.

The following graphs show the load and displacement recorded for the specimens:

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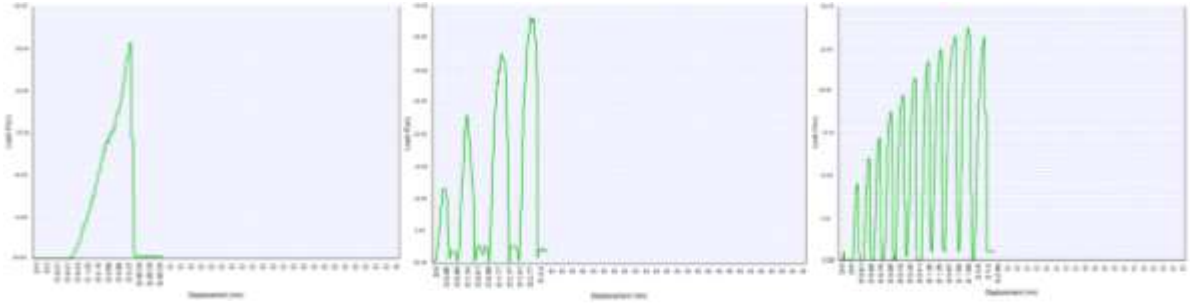

Fig 8: M40 Cylinder under Monotonic, point load Cyclic and 2-Point load Cyclic Loading.

Fig 9: M40 Cylinder under Stability Loading, M65 Cylinder under Monotonic Loading.

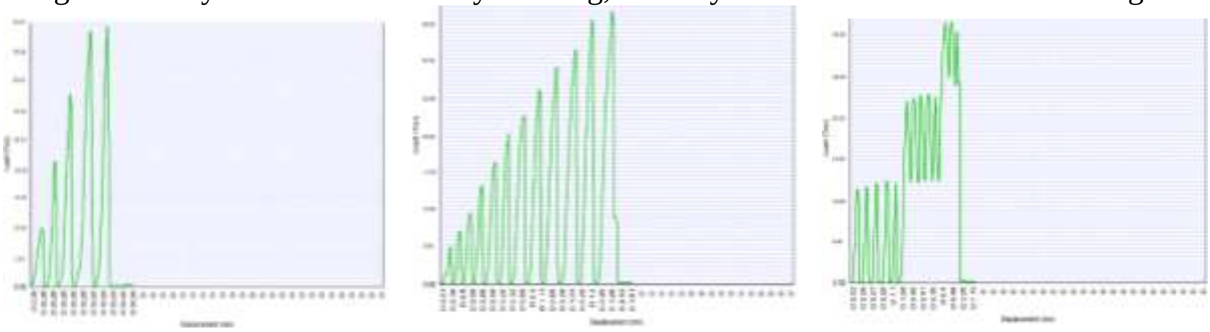

Fig 10: M65 Cylinder under Point load Cyclic, 2-Point load Cyclic and Stability Loading.

5.5 Behavior of M40 & M65 grade Precast Panels under various Loadings:

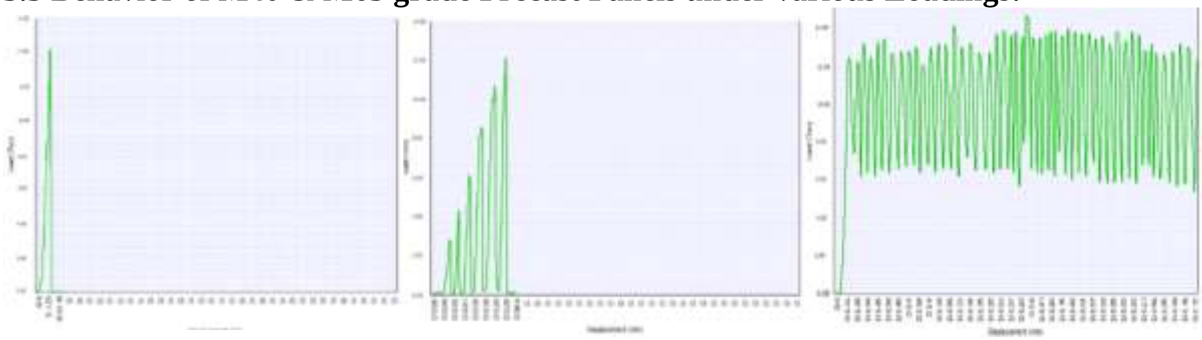

Fig. 11 M40 grade PRP under Monotonic, Cyclic Loading and Fatigue loading cycles.

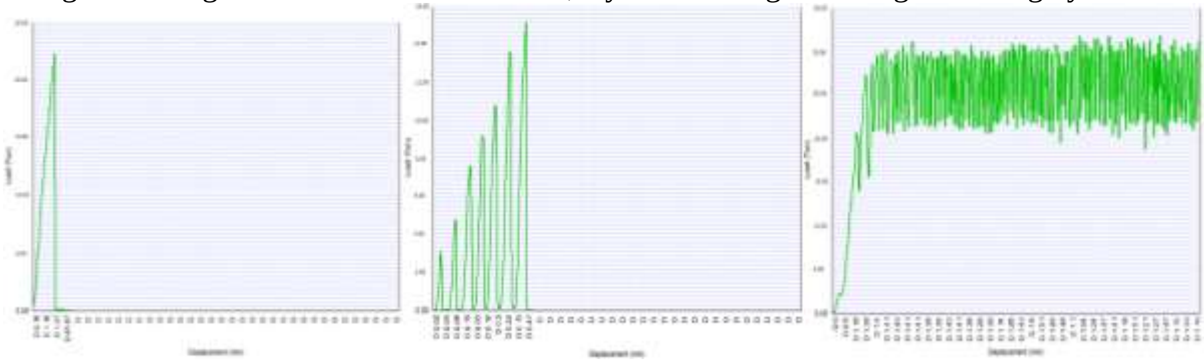

Fig 12: M65 grade PRP under Monotonic, Cyclic Loading and Fatigue loading cycles.

These values were recorded with the help of data logger using LVDT (linear variable differential transducer) and dial gauge. Load cell was placed on the specimen and cycles were applied manually using a lever by hydraulic press.

Fig 13: Images show Data logger, Laptop and the Set-up used for testing of specimens.

Stress-Strain Curve for M40 and M65 grade Cylinders:

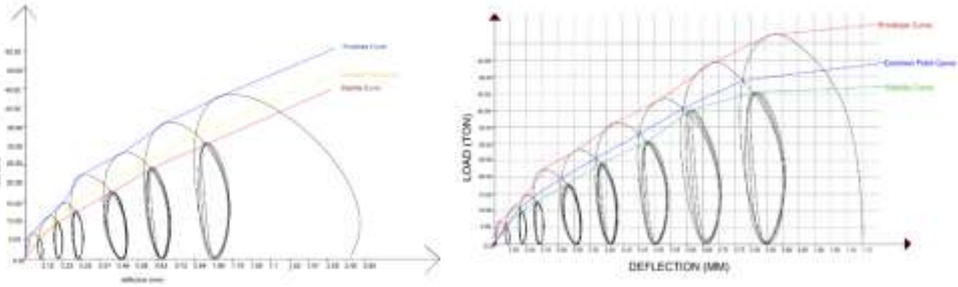

Fig.14: Stress Strain Curve for M40 grade Cylinders under Stability test.

Stress-Strain Curve for M40 and M65 grade PRPs:

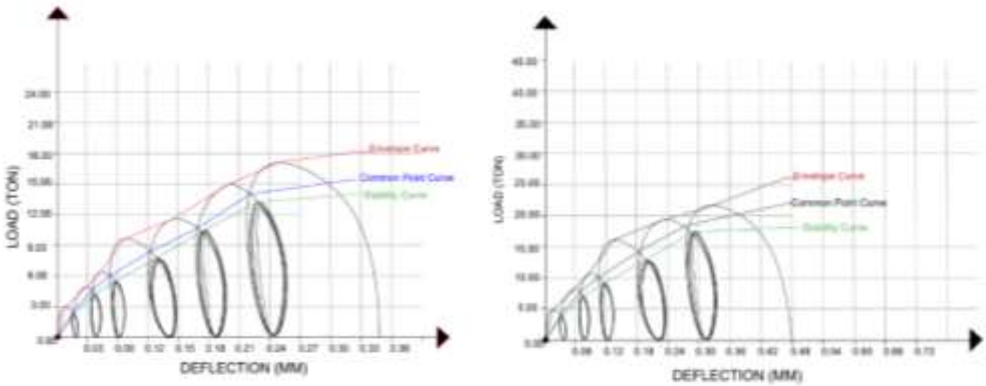

Fig.15: Stress Strain Curve for M40 and M65 grade PRP under stability test.

Envelope point is the point of maximum stress-strain value in the domain of any loading curve would not exceed until we get the visible failure. Common point is the point of intersection of the reloading curve of any cycle with the unloading curve of the previous cycle. Stability point is the point where common point stabilized at the lower bound. Envelope point curve is defined as the locus of limiting stress value in each domain, could not exceed by any loading curve. Common point curve is the locus of points where the reloading curve of any cycle crosses the unloading curve of the previous cycle. Stability point curve is the locus of stability points is termed as stability point curve.

Failure Patterns of the Specimens:



VI. Conclusion:

From the above results, it is clear that Soybean Husk Ash and Kota Stone Dust can be used as a cement replacement material because of their good pozzolanic properties. Compressive strength, Flexural Strength and Split Tensile Strength of concrete of both M40 and M65 grades of concrete were almost similar to nominal mix or increased by 5%-10%. Increasing more than 10% of SHA and 15% KSD quantity of replacement materials led to decrement in the strength parameters. The 7-day results of M40 and M65 cylinders with SHA and KSD under monotonic loading cycles took loads of 39.86 tonnes and 51.60 tonne respectively. The 7-day results of M40 and M65 cylinders with SHA and KSD under cyclic loading took loads of 37.45 tonnes and 44.92 tonnes respectively. The 7-day results of M40 and M65 cylinders with SHA and KSD under cyclic loading took loads of 33.27 tonnes and 32.59 tonnes respectively. The behaviour of M40 panels with SHA and KSD under monotonic loading took loads of 14.08 tonnes, under cyclic loading: 12.29 tonnes and under Fatigue: cycles of 6.00-12 tonnes were applied for n number of cycles till failure. The behaviour of M65 panels with SHA and KSD under monotonic loading took loads of 27.56 tonnes, under cyclic loading: 24.13 tonnes and under Fatigue: cycles of 12 - 18 tonnes were applied for n number of cycles till failure. Under cyclic loading the specimens with different grades of concrete fall in the range of 75-90% of monotonic loading. Peak stresses corresponding to a common point and stability point is 70-90% of the envelope curve. The experimental repeated measurements yielded an envelope stress-strain curve, a locus of common points, and a locus of stability points. Curves of stress and strain. The stability point curve is used to define the Design mixes allowable stress limits, where compressive strength degradation due to repetitive loading must be taken into account. The cyclic stress-strain curve was used to establish the location of common and stability points. This helps in developing block shear diagrams of DM possessing 10% of SSA & 15% each of KSD content. Peak stresses corresponding to the common point is more than 75% of the envelope curve. Peak stresses corresponding to stability points are more than 65% of the envelope curve. Load cycles with peak stresses of the stability point curve clearly show accumulation of plastic strain below which strain stabilizes and hence below which model could not be failed.

References

[1] A. Syed and R. Sonparote, “A review of precast concrete pavement technology,” Baltic Journal of Road and Bridge Engineering, vol. 15, no. 4, pp. 22–53, 2020, doi: 10.7250/bjrbe.2020-15.493.
[2] K. J. Taku and Y. D. Amartey, “Suitability study of soybeans husk ash as a mixing material to OPC: Effect of calcination time-preliminary investigation,” Kathmandu University Journal of Science, Engineering and Technology, vol. 12, no. 1, pp. 13–22, Nov.2018, doi: 10.3126/kuset.v12i1.21561.
[3] P. Nath and P. Sarker, “Effect of fly ash on the durability properties of high strength concrete,” in Procedia Engineering, 2011, vol. 14, pp. 1149–1156. doi: 10.1016/j.proeng.2011.07.144.
[4] R. Tomek, “Advantages of Precast Concrete in Highway Infrastructure Construction,” in Procedia Engineering, 2017, vol. 196, pp. 176–180. doi: 10.1016/j.proeng.2017.07.188.

[5] Tiwari v., "Experimental Study Of Fly-Ash Brick Masonry Under subjected To cyclic Loading" IJSTE–International Journal of Science Technology & Engineering| Vol. 1, Issue 1, July 2014| ISSN (online): 2349-784
[6] S. Tayabji, D. Ye, and N. Buch, "Precast concrete pavements: Technology overview and technical considerations," PCI Journal, vol. 58, no. 1. Precast/Prestressed Concrete Institute, pp. 112–128, 2013. doi: 10.15554/pcij.01012013.112.128.
[7] Bureau of Indian Standards, "IS 456 (2000): Plain and Reinforced Concrete - Code of Practice."
[8] Bureau of Indian Standards, "IS 1727 (1967): Methods of test for pozzolanic materials," 1968.
[9] Bureau of Indian Standards, "IS 4032 (1985): Method of chemical analysis of hydraulic cement.
[10] Indian Road Congress, "IRC 44-2017: Guidelines for cement concrete mix design for pavements".
[11] Indian Road Congress, "IRC 58-2015: Guidelines for the Design of Plain Jointed Rigid Pavements for Highways".
[12] S. Supic, "Reactivity and pozzolanic properties of biomass ashes generated by wheat and soybean straw combustion," Materials, vol. 14, no. 4, pp. 1–20,Feb.2021, doi: 10.3390/ma14041004.
[13] Harshwardhan SC, Pawan Kalla, Ravindra Nagar et al. Partial Replacement of Cement by Kota Stone Slurry in Mortar. Recent Trends in Civil Engineering & Technology. 2017; 7(3): 8–13p.
[14] L. Krishnaraj and P. T. Ravichandran, "Investigation on grinding impact of fly ash particles and its characterization analysis in cement mortar composites," Ain Shams Engineering Journal, vol. 10, no. 2, pp. 267–274, Jun. 2019, doi: 10.1016/j.asej.2019.02.001.
[15] A. Syed and R. Sonparote, "A review of precast concrete pavement technology," Baltic Journal of Road and Bridge Engineering, vol. 15, no. 4, pp. 22–53, 2020, doi: 10.7250/bjrbe.2020-15.493.
[16] M. I. Albiajawi, R. Embong, and K. Muthusamy, "An overview of the utilization and method for improving pozzolanic performance of agricultural and industrial wastes in concrete," in Materials Today: Proceedings, 2021, vol. 48, pp. 778–783. doi: 10.1016/j.matpr.2021.02.260.